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Tactical Decision Aid Codes provide field prediction of maximum range for FLIR use using simplified local environmental parameter input. A series of experimental comparisons at sea using airborne operational FLIRs with an instrumented ship target have shown poor correlation of observed range with prediction for detection for detection and recognition. Classification and recognition range in UFLR are found to be highly insensitive to radiosonde atmospheric profile data input. Previous work has addressed modeling of the average target to background contrast temperature difference and atmospheric propagation of contrast. This paper addresses the implementation of the MDTD and MRTD algorithms in the code. Comparisons are presented of the prediction accuracy of the UFLR TDA using the standard Moser/Hepfer algorithm and an adaptation of the Johnson criterion used in the NVEOL Ratches code. For the limited data set of the study a reduction of RMS prediction error is achieved using the NVEOL algorithm.

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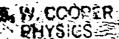| 17. Security Classification of Report. Unclassified	18. Security Classification of This Page. Unclassified	19. Security Classification of Abstract. Unclassified	20. Limitation of Abstract. SAR

Characterization, Propagation, and Simulation of Sources and Backgrounds II

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Evaluation of tactical decision aid code predictions of FLIR
range performance.

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ABSTRACT

Tactical Decision Aid codes provide field prediction of maximum range for FLIR use using simplified local environmental parameter input. A series of experimental comparisons at sea using airborne operational FLIRs with an instrumented ship target have shown poor correlation of observed range with prediction for detection and recognition. Classification and recognition range in UFLR are found to be highly insensitive to radiosonde atmospheric profile data input. Previous work has addressed modeling of the average target to background contrast temperature difference and atmospheric propagation of contrast. This paper addresses the implementation of the MDTD and MRTD algorithms in the code. Comparisons are presented of the prediction accuracy of the UFLR TDA using the standard Moser/Hepfer algorithm and an adaptation of the Johnson criterion used in the NVEOL Ratches code. For the limited data set of the study a reduction of RMS prediction error is achieved using the NVEOL algorithm.

1. INTRODUCTION:

A Tactical Decision Aid (TDA) code such as the Forward Looking InfraRed range prediction codes evaluated in this study is a simplified computer model designed for application, for example, by a Navy aircrew at pre-flight briefing. It consists typically of (a) a target model giving a contrast temperature difference (ΔT) against an appropriate background, (b) a propagation model to project this contrast from the target location to the sensor, and (c) a sensor performance model specifying a Minimum Detectable Temperature Difference (MDTD) for target detection or a Minimum Resolvable Temperature Difference (MRTD or MRT) for classification or recognition. Target inputs for currently operational navy FLIR TDAs range from menu selection of standard target type and size to a complex faceted heat-balance model providing aspect-dependent target area and average temperature. The propagation of the apparent contast ΔT to the sensor is computed typically from some derivative of LOWTRAN output based on a measured marine boundary layer vertical profile. Maximum range is determined by application of a defined apparent ΔT criterion for detection or recognition at a selected probability (eg 50%). TDAs currently in use in the Navy include the FLIR performance module UFLR incorporated in the Tactical Environmental Support System (TESS) and the EOTDA (MKIII) adapted from the Air Force for naval use.

For a number of years the Naval Academic Center for Infrared Technology at the Naval Postgraduate School has been conducting a series of validation measurements in cooperation with NRL Monterey (formerly NOARL West), using the 135 foot, 294 ton Research Vessel POINT SUR as an instrumented target for operational FLIR-carrying naval aircraft. The object of these measurements has been the comparison of observed with predicted ranges under conditions in which the environmental factors are accurately known. Series of measurements have been made from 1986 to 1990, in conjunction with a variety of aircraft (and FLIR) types. The summarized observations from these tests and predictions of the UFLR code have been compared previously[1,2]. Comparisons have been made using the UFLR code, the EOTDA MKII and MKIII, and in all cases significant discrepancies have been found. UFLRB, a modification of UFLR to include sky reflection and real target dimensions and temperature difference, has shown only minor performance improvement over UFLR. With the adaptation of the EOTDA to naval targets further comparisons have been made[3] still without satisfactory agreement. The objective of this paper is to consider the detection or recognition criterion as a source of error. This analysis concentrates on data taken in Monterey Bay during the measurement period 2 to 7 November 1989, compared with the TESS-UFLR code.

2. CHARACTERISTICS OF EXISTING TDA CODES.

The UFLR operational TDA code[4] used for the analyses in this paper was adapted by the Naval Environmental Prediction Research Facility from the PREOS code developed by the Naval Ocean Systems Center. UFLR is used in two versions: TESS-UFLR incorporated in the navy's Tactical Environmental Support System (TESS) for field use, and FNOC-UFLR, a central site version used by Fleet Numerical Oceanography Center for worldwide prediction based on a forecast atmospheric structure data set. UFLR provides ranges for detection, categorization and recognition of targets as a function of aircraft altitude. TESS-UFLR uses local atmospheric profile data from the Atmospheric Environmental File of TESS, and requires keyboard input of surface wind speed and visibility. Aircraft or FLIR type is menu selected; UFLR supports all navy FLIRs. Target type is selected from a menu of marine targets, each represented by fixed effective dimensions and fixed contrast temperature. Atmospheric propagation is computed with a parameterized version of LOWTRAN3B with the Katz-Rhunke aerosol extinction model, and a layered atmosphere limited by the resolution of the vertical profile data.

The MKIII EOTDA is an adaptation of the Air Force Electro-Optical TDA developed and maintained by AFGL. MKIII supports many navy FLIRS including that used in this study, and incorporates a ship signature model (TCM2) developed by Georgia Tech Research Institute. TCM2 treats internal heat sources and reflection and absorption of solar and sky radiation, and outputs an aspect-dependent average temperature and effective area. A simple sea surface radiance model including emitted and reflected radiance from the wind-ruffled surface is used for target thermal contrast.

3. MEASUREMENT PROCEDURES.

The R/V POINT SUR is a research ship owned by the National Science Foundation and operated by Moss Landing Marine Laboratories for a consortium of West Coast institutions including NPS. For the measurements reported here the ship was equipped with an array of thermistor sensors for ship skin temperature distribution measurement, and data were recorded continuously from a full suite of meteorological and oceanographic instruments. Hourly observations were recorded of position, ship speed and heading, surface wind speed and direction, air temperature, pressure and humidity, cloud cover, precipitation, visibility, sea state, and sea surface temperature. Rawinsonde probes were launched from shipboard to profile the atmosphere up to 10,000 feet. FLIR range observations for detection, classification and recognition were made from navy Marine Patrol (MPA) aircraft during seventeen overflights grouped into four periods spread over a week. These sorties comprise 9 day and 8 night passes. Only the detection range data are discussed in this paper.

The first three measurement periods experienced weak onshore surface wind and calm seas, with weak surface pressure gradients and high pressure aloft. The boundary layer was confined to about 1000 feet by the subsidence inversion. The last measurement period was affected by the passage of a low pressure area, with increased on-shore surface winds and some haze and low stratus clouds. The boundary layer extended to about 2600 feet.

4. RESULTS

The observed and computed data are summarized in Table 1. The measurements are grouped into the periods around 0600 GMT, Nov 2, 1989 (2200 Local Solar Time, (LST) Nov 1) and 1000 GMT Nov. 2 (0200 LST, 2 Nov.), 0100 GMT, 3 Nov (1700 LST, 2 Nov) and 2200 GMT Nov 7 (1400 LST, 7 Nov). These time periods are represented in the following figures by the symbols circles, triangles, squares and diamonds respectively.

The observed ranges of Table 1 are shown in Figure 1 plotted against the predictions of the UFLR and EOTDA codes. Figure 1a shows predictions using the standard UFLR code with the "small combattant" target input from the menu. This shows a large degree of scatter; the linear regression line drawn indicates significant overprediction, and a coefficient of determination r^2 of 0.44. Figure 1b, from the Mk II EOTDA using the standard UFLR target (since MkII does not internally support ship targets) surprisingly shows significant underprediction, but much less vertical scatter, and an r^2 of only 0.24. Figure 1c using the TCM2 model specifically of the R/V POINT SUR in the MKIII EOTDA shows closer numerical agreement but an r^2 of only 0.07. This target model computes effective area and temperature difference

for the real target, in this case the R/V POINT SUR. These low correlations lead to consideration of a source of discrepancy other than the target contrast. In the following sections the criterion for detection and the MDTD/MRTD are considered.

5. ANALYSIS

5.1 Criteria for Detection and Recognition Range.

The UFLR FLIR program computes the maximum range for detection, categorization and recognition, defined by the condition that the perceived target-to-background temperature difference is equal to the system Minimum Detectable Temperature Difference, MDTD, for detection, or the Minimum Resolvable Temperature Difference MRTD with the required degree of resolution. The form of MDTD adapted from Hepfer[4] represents "single pixel" or "Star" detection.

For categorization or recognition the UFLR code incorporates the pixel resolution criterion developed by Moser [5], incorporating Hepfer's modification for eye spatial filtering for small targets. This describes the resolution required for a given level of discrimination by a required number of resolution pixels within the total image of the target, described as an equivalent square area.

The application of MRT and MDT models to discrimination of displayed images of real scene objects and to range prediction has been discussed by Rosell[6]. The classic Johnson criterion[7] for visual discrimination replaces the real scene with a bar pattern of similar contrast to the real target, with the maximum number of bars resolvable across the minimum target dimension. The Ratches (NVEOL)[8] code incorporated a system of multiple discrimination levels defined in terms of lines per minimum object dimension, distinguishing three different discrimination levels for detection, depending on background clutter. In this scheme, the lowest level detection (level 0) requires 1-3 lines per critical dimension. In this study the applicability of higher level discrimination detection was investigated by application of the NVL three-bar detection criterion to range prediction in UFLR.

5.2   Ship Range Prediction with the NVEOL Criterion.

The basis of comparison between the Moser/Hepfer criterion for detection or recognition as implemented in the UFLR code and the Johnson criteria used in the Ratches (NVEOL) code is the detection or recognition range. Past experience has shown that the standard UFLR small combatant target is a poor representation of the R/V POINT SUR and that an accurate assessment of the effective target size and apparent ΔT is beneficial for TDA comparisons. An appropriate model for target calculation is the Thermal Contrast Model Version 2 (TCM2), developed at the Georgia Tech Research Institute (GTRI), and implemented in the Mark III EOTDA[9]. A stand-alone version of TCM2 was executed with extensive input meteorological data sets and with target/sensor geometry defined by the observed detection ranges and flight profiles. The output of the faceted ship model was reduced to the effective target dimensions and apparent ΔT between the target and the sea in the field of view as shown in Table 1. The GTRI TCM2 model utilizes a simple algorithm to account for the variable emissivity of the wind-roughened sea surface and the influence of reflected downdwelling sky radiation. A more robust model of the IR radiance of the sea surface has been developed by Wollenweber[10] at NOSC which utilizes an enhanced version of LOWTRAN 6. Apparent ΔT between the TCM2 ship target and the NOSC effective sea surface temperature (SST) algorithm are also shown in Table 1 as well as ΔTs computed between the TCM2 target and the horizon sky, where the horizon sky was modelled as a blackbody at ambient temperature[11].

The effective ship dimensions and the three sets of apparent target/background ΔTs were implemented in UFLR using the Moser/Hepfer detection criterion, and the predicted range results are shown in Figures 2a-2c and summarized in Table 2. Each symbol represents a different measurement period, with open symbols corresponding to daytime and filled corresponding to nighttime. Comparison between these figures and with Figure 1a shows that a more accurate specification of effective target size and apparent delta-T improves the detection range predictions from 11.7 nmi RMS error and correlation of 0.64 using the unmodified UFLR target model to 4.3 nmi RMS error and correlation of 0.73 using the TCM2 target and the horizon sky as background. This is surprising since calculations based on target height

land sensor altitude and depression angle show that with the exception of a single case, the ship target at detection is completely within the water background in the sensor's field of view. The corresponding ΔT values in Table 1 show that the average magnitude of the apparent ΔT for the horizon background is smallest, 2.34° C versus 2.87° C for the GTRI model and 3.26° C for the NOSC mode; the standard UFLR ship target has a fixed 5.0°C apparent ΔT.

For comparison with the UFLR detection criterion, the Johnson detection/recognition criterion was adapted from the NVEOL Ratches FLIR model and implemented in UFLR in place of the standard Moser/Hepfer detection algorithm. A problem has been known to exist in the definition of the critical dimension for a large aspect-ratio target[8]. In this study three easily implemented forms for critical dimension have been used. The critical dimension for detection in UFLR is the side of an equivalent square target, $(xy)^{1/2}$; the predicted ranges using this target dimension in the NVEOL algorithm are shown in Figures 3a - 3c for the same three apparent ΔT models. These ranges are predicted at the 50% probability of detection level. The results show less scatter than for the Moser/Hepfer criterion, with the smallest RMS error (3.9 nmi) and the largest correlation (.72) associated again with the horizon background. From Table 2, the GTRI SST background gives the worst RMS error of 5.8 nmi and lowest correlation of 0.58 compared with the NOSC SST background results of 4.6 nmi RMS error and correlation 0.60.

The predictions of Figure 4 were obtained similarly but using the effective horizontal (x) dimension of the target as critical dimension in the NVEOL algorithm. From the beam aspect most detail might be expected in this dimension. For each of the sea backgrounds the scatter of the data is increased with a resultant increase in RMS error and also in correlation; the horizon sky background however shows a slight decrease in correlation.

For the predictions of Figure 5 the vertical (y) dimension of the target (fixed for the R/V POINT SUR at 8.8 meters) has been used as the critical dimension for detection. This is the smallest of the three dimensions used and results in the shortest ranges and the smallest RMS errors. From Table 2 we find that the smallest RMS error of 3.0 nmi is associated with the horizon background, which also has a correlation of 0.72, close to that for the square target and horizon sky results shown in Figure 3c.

6. CONCLUSIONS

Previous comparisons of observed FLIR detection ranges with predictions made using the UFLR model have shown considerable scatter, extreme overprediction, and poor correlation. Previous improvements in the target/background model and atmospheric transmittance model have yielded marginal increases in prediction accuracy. The latest modification of UFLR to include the NVL Ratches model implementation of the Johnson Criterion has shown additional improvement with this limited data set. RMS errors have been reduced from nearly 12 nmi to under 3 nmi with an accompanying small increase in the correlation coefficient. Most importantly, the extreme overpredictions associated with UFLR have been reduced. Other factors which may affect the detectibility of targets but have not been considered here may include IR sea clutter, white caps, and sea spray. Human factors may also be significant.

Several aspects of the NVL algorithm should be evaluated further for use with ship targets. It is not clear how the critical dimension for target detection should be defined, taking into account the large hull form and sparse superstructure and aspect ratio change with viewing angle. Human factors and the appropriate level of discrimination for ship detection should be further considered.

7. ACKNOWLEDGEMENTS.

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